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Narasin effects on energy, nutrient, and fiber digestibility in corn-soybean meal or corn-soybean meal-dried distillers grains with solubles diets fed to 16-, 92-, and 141-kg pigs

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Abstract

Three experiments were conducted to determine the effect of narasin on growth performance and on GE and nutrient digestibility in nursery, grower, and finishing pigs fed either a corn-soybean meal (CSBM) diet or a CSBM diet supplemented with distillers dried grains with solubles (DDGS), in combination with either 0 or 30 mg narasin/kg of diet. In Exp. 1 (64 gilts, initial BW = 9.0 kg, SD = 1.0 kg) and Exp. 2 (60 gilts. initial BW = 81.1 kg, SD = 6.1 kg), gilts were allotted into individual pens and fed their experimental diets for 24 and 21 d, respectively. On the last 2 d of each experiment, fecal samples were collected to assess apparent total tract digestibility (ATTD) of GE and various nutrients. In Exp. 3, 2 separate groups of 24 gilts (initial BW = 145.1 kg, SD = 7.8 kg) were allotted to individual metabolism crates and fed their experimental diets for 30 d prior to a time-based 6-d total fecal collection period to assess GE and nutrient digestibility. In Exp. 1, there was an interaction between diet type and narasin addition for G:F and for many of the ATTD coefficients measured. When narasin was supplemented to the CSBM diet, ATTD of GE, DM, C, S, phosphorus, NDF, and ADF was either not changed or reduced, while when narasin was supplemented to DDGS diets, these same ATTD parameters were increased (interaction, $P \leq 0.05$). Even though ADG and ADFI were not affected, G:F] was improved in pigs fed the CSBM diet with supplemental narasin, but was reduced in pigs fed the DDGS diet with supplemental narasin (interaction, $P < 0.05$). In Exp. 2, there was an interaction between diet type and narasin supplementation only for ATTD of Ca (interaction, $P < 0.01$), in that narasin supplementation did not change the ATTD of Ca in pigs fed the CSBM diet, while narasin supplementation reduced the ATTD of Ca in pigs fed the DDGS containing diet. In Exp. 3, there was an interaction between diet and narasin only for ATTD of C (interaction, $P < 0.01$) in that narasin supplementation resulted in an increased ATTD of C in pigs fed the CSBM diet, while narasin supplementation to the DDGS containing diet resulted in a reduced ATTD of Ca. In general, the data indicate that narasin interacted with and had its largest effect on pig performance and GE or nutrient digestibility in 9 to 23 kg pigs compared to pigs weighing greater than 80 kg. The data also indicate that the addition of DDGS reduced GE, DM, Ca, and N digestibility, regardless of BW.

Keywords

corn distillers dried grains with solubles, digestibility, energy, narasin, pigs

Disciplines

Agriculture | Animal Sciences | Bioresource and Agricultural Engineering | Meat Science

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Narasin effects on energy, nutrient, and fiber digestibility in corn-soybean meal or corn-soybean meal-dried distillers grains with solubles diets fed to 16-, 92-, and 141-kg pigs[1]

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ABSTRACT: Three experiments were conducted to determine the effect of narasin on growth performance and on GE and nutrient digestibility in nursery, grower, and finishing pigs fed either a corn-soybean meal (CSBM) diet or a CSBM diet supplemented with distillers dried grains with solubles (DDGS), in combination with either 0 or 30 mg narasin/kg of diet. In Exp. 1 (64 gilts, initial BW = 9.0 kg, SD = 1.0 kg) and Exp. 2 (60 gilts. initial BW = 81.1 kg, SD = 6.1 kg), gilts were allotted into individual pens and fed their experimental diets for 24 and 21 d, respectively. On the last 2 d of each experiment, fecal samples were collected to assess apparent total tract digestibility (ATTD) of GE and various nutrients. In Exp. 3, 2 separate groups of 24 gilts (initial BW = 145.1 kg, SD = 7.8 kg) were allotted to individual metabolism crates and fed their experimental diets for 30 d prior to a time-based 6-d total fecal collection period to assess GE and nutrient digestibility. In Exp. 1, there was an interaction between diet type and narasin addition for G:F and for many of the ATTD coefficients measured. When narasin was supplemented to the CSBM diet, ATTD of GE, DM, C, S, phosphorus, NDF, and ADF was either not changed or reduced, while when narasin was supplemented to DDGS diets, these same ATTD parameters were increased (interaction, $P \leq 0.05$). Even though ADG and ADFI were not affected, G:F] was improved in pigs fed the CSBM diet with supplemental narasin, but was reduced in pigs fed the DDGS diet with supplemental narasin (interaction, $P < 0.05$). In Exp. 2, there was an interaction between diet type and narasin supplementation only for ATTD of Ca (interaction, $P < 0.01$), in that narasin supplementation did not change the ATTD of Ca in pigs fed the CSBM diet, while narasin supplementation reduced the ATTD of Ca in pigs fed the DDGS containing diet. In Exp. 3, there was an interaction between diet and narasin only for ATTD of C (interaction, $P < 0.01$) in that narasin supplementation resulted in an increased ATTD of C in pigs fed the CSBM diet, while narasin supplementation to the DDGS containing diet resulted in a reduced ATTD of Ca. In general, the data indicate that narasin interacted with and had its largest effect on pig performance and GE or nutrient digestibility in 9 to 23 kg pigs compared to pigs weighing greater than 80 kg. The data also indicate that the addition of DDGS reduced GE, DM, Ca, and N digestibility, regardless of BW.

Key words: corn distillers dried grains with solubles, digestibility, energy, narasin, pigs

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INTRODUCTION

The structure of lipophilic ionophores allows for attachment to cell membranes of bacteria, with a higher affinity toward Gram-positive bacteria, fungi, and coccidia compared to Gram-negative bacteria (Miyazaki et al., 1974; Schelling, 1984; Russell, 1987). In growing pigs, salinomycin has been shown to increase pig performance when fed a corn-soybean meal (**CSBM**; Blair and Shires, 1981; Leeson et al., 1981;

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Lindemann et al., 1985) or a fiber-rich diet (Wheelhouse and Groves, 1985). Likewise, monensin has also been shown to improve G:F in pigs fed a barley-soybean-meal-based diet (Kirkwood et al., 1990). In contrast, Thacker et al. (1992) and Van Lunen et al. (1992) reported no effect of ionophore supplementation on growing pig performance. Ionophores may also impact hind gut bacterial fermentation processes as shown by a decrease in the acetate:proprionate ratio in pigs fed lasalocid (Holzgraefe et al., 1985a) or salinomycin (Marounek et al., 1997). Holzgraefe et al. (1985b) reported that lasalocid added to sows diets containing either CSBM or corn-hay-based diet numerically improved fiber and N digestion, but not GE utilization, while Moore et al. (1986a) reported that salinomycin influenced GE and N utilization in pigs fed diets containing wheat bran, but not in pigs fed a CSBM or a diet containing oat hulls. Lastly, Thacker et al. (1992) reported that salinomycin improved the digestibility of CP or GE in the rye-based diet, but not in pigs fed the barley-based diet. Narasin has also been shown to increase the relative concentrations of propionic acid in the large intestine and improve N digestibility in pigs fed a CSBM diet (Wuethrich et al., 1998) and improve pig performance (Arkfeld et al., 2015). The objectives of this study were to evaluate the ability of narasin to affect growth performance and GE and nutrient digestibility in nursery, grower, and finishing pigs fed either CSBM or a diet containing distillers dried grains with solubles (**DDGS**).

MATERIALS AND METHODS

All experiments were approved by the Iowa State University Animal Care and Use Committee.

Diets and Experimental Design

In each of 3 experiments, gilts (Camborough 22 sows × L337 boars; Pig Improvement Company, Hendersonville, TN) were fed either a low-fiber, CSBM diet or a higher-fiber diet containing DDGS (Table 1). All diets were formulated to meet or exceed the energy, AA, and mineral needs according to the NRC (2012) recommendations. Titanium dioxide was added as an indigestible marker at 0.5% of the diets in Exp. 1 and 2 to determine apparent total tract energy and nutrient digestibility by the indirect method: $[1-((\mathrm{Ti}_{feed} \times \mathrm{nutrient}_{feces})/(\mathrm{Ti}_{feces} \times \mathrm{nutrient}_{feed}))]$. Diets containing narasin, 30 mg/kg diet, were accomplished by adding the narasin premix (Skycis™ 100; Elanco Animal Health, Indianapolis, IN) at the expense of corn.

In Exp. 1, 64 gilts (initial BW = 9.0 kg, SD = 1.0 kg) were randomly allotted into individual pens measuring 0.46 × 1.22 m, resulting in 16 pigs per treatment. In Exp. 2, 60 gilts (initial BW = 81.1 kg, SD = 6.1 kg) were randomly allotted to individual pens measuring 1.0 × 1.8 m, resulting in 15 pigs per treatment. In Exp. 1 and 2, pigs and feeders were weighed at the beginning and end of the experimental period to calculate ADG, ADFI, and G:F. In Exp. 1 and 2, pigs were fed their experimental diets for 24 and 21 d, respectively, and allowed ad libitum access to feed and water. Each room was maintained with 24-h lighting, was mechanically ventilated, and had a pull-plug manure storage system. Experimental diets were fed in meal form with dietary treatments randomly assigned to pig within pen. On the last 2 d of each experiment, fecal samples were collected obtaining a grab sample of freshly voided feces and then stored at 0°C.

In Exp. 3, 2 separate groups of 24 gilts (initial BW = 145.1 kg, SD = 7.8 kg) were randomly allotted to individual metabolism crates (1.2 × 2.4 m) that allowed for total but separate collection of feces and urine. Crates were equipped with a stainless steel feeder and a nipple waterer, to which the pigs had ad libitum access. Ambient temperature in the metabolism room was maintained at approximately 21°C, and lighting was provided continuously. Pigs were fed twice daily (0700 and 1900 h) a total amount of feed that approximated 3% of their BW. Actual feed intake (feed offered less, feed not consumed) was utilized for all digestibility calculations. Pigs were fed the dietary treatments for 30 d prior to a 6-d collection period. During the time-based 6-d total fecal collection period, feces were collected twice daily and stored at 0°C until the end of the collection period. Feces were pooled by pig over the 6 d period and stored at 0°C.

Analytical Methods

At the end of each experiment, diets and feces were dried in a 70°C forced-air oven, weighed, ground through a 1-mm screen, and a subsample was retained for analysis. Diet and fecal samples were analyzed in duplicate. Carbon, N, and S were analyzed using thermocombustion (VarioMax; Elementar Analysensysteme GmbH, Hanau, Germany). Acid and neutral detergent fibers were analyzed using filter-bag technology (Ankom2000, method # 8-ADF, method #9-NDF; Ankom Technology, Macedon, NY). Gross energy was determined using an isoperibol bomb calorimeter (Model 1281; Parr Instrument Co., Moline, IL), with benzoic acid used as a standard. Calcium and phosphorus were analyzed by digesting the sample with concentrated nitric acid following method (II)A (AMC, 1969), with the residue dissolved in 1N HCl followed by inductively coupled plasma spectrometry (Optima 5300DV; PerkinElmer, Shelton, CT). Titanium dioxide (Exp. 1 and 2) was analyzed in the feed and feces (Exp. 1 and 2) by digesting the samples in sulfuric acid, and hydrogen peroxide and subsequent

Table 1. Experimental diet formulation, as-is basis

	Exp. 1[1]		Exp. 2[2]		Exp. 3[3]	
Ingredient, %	CSBM[4]	DDGS[4]	CSBM[4]	DDGS[4]	CSBM[4]	DDGS[4]
Corn	59.29	48.35	84.50	66.88	82.02	66.70
Soybean meal	21.10	12.10	12.50	–	15.60	–
DDGS[4]	–	20.00	–	30.00	–	30.34
Whey	10.00	10.00	–	–	–	–
Fish meal	5.00	5.00	–	–	–	–
Porcine plasma	1.25	1.25	–	–	–	–
Soybean oil	0.38	0.17	0.12	–	–	0.32
Monocalcium phosphate	0.19	–	0.54	0.23	0.74	0.38
Limestone	0.97	1.10	0.89	1.12	0.83	1.09
Titanium dioxide	0.50	0.50	0.50	0.50	–	–
Sodium chloride	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin mix[5]	0.20	0.20	0.15	0.15	0.15	0.15
Trace mineral mix[6]	0.20	0.20	0.20	0.20	0.20	0.20
L-lysine·HCl	0.36	0.54	0.21	0.46	0.11	0.46
DL-methionine	0.12	0.10	–	–	–	–
L-threonine	0.09	0.11	0.04	0.07	–	0.07
L-tryptophan	–	0.03	–	0.04	–	0.04
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated composition, %						
ME, kcal/kg	3,325	3,325	3,300	3,300	3,305	3,345
NE, kcal/kg	2,473	2,445	2,528	2,490	2,516	2,516
CP, %	20.7	21.2	13.2	14.2	14.3	14.3
sidLys, %	1.3	1.3	0.65	0.65	0.65	0.65
Ca, %	0.74	0.74	0.48	0.48	0.48	0.48
P, %	0.58	0.56	0.42	0.40	0.45	0.41
sttdP, %	0.36	0.36	0.22	0.22	0.23	0.23
S, %	0.28	0.36	0.16	0.30	0.17	0.30
NDF, %	7.1	13.0	8.7	17.5	8.7	17.5
Analyzed composition, %						
GE, kcal/kg	3,867	3,991	3,703	3,959	3,797	4,056
DE, kcal/kg[7]	3,229	3,154	3,310	3,122	3,423	3,469
CP, %	20.9	21.1	12.8	13.7	13.8	13.8
C, %	39.5	40.5	38.4	40.3	38.9	40.5
Ca, %	0.83	0.85	0.61	0.55	0.54	0.50
P, %	0.55	0.58	0.38	0.43	0.46	0.47
S, %	0.30	0.35	0.17	0.24	0.19	0.26
NDF, %	6.0	10.1	7.4	12.7	6.7	12.8

[1]Diets formulated to contain a minimum of 0.55 TSAA:Lys, 0.585 Thr:Lys, 0.165 Trp:Lys, 0.515 Ile:Lys, 0.64 Val:Lys.

[2]Diets formulated to contain a minimum of 0.58 TSAA:Lys, 0.65 Thr:Lys, 0.175 Trp:Lys, 0.53 Ile:Lys, 0.68 Val:Lys

[3]Diets formulated to contain a minimum of 0.58 TSAA:Lys, 0.65 Thr:Lys, 0.175 Trp:Lys, 0.53 Ile:Lys, 0.68 Val:Lys. Diets for Exp. 3 were formulated to be equal in NE, at 2,515 kcal/kg.

[4]Abbreviations: CSBM = corn-soybean meal based, DDGS = corn-distillers dried grains with solubles based diet. Narasin treatment diets (30 mg/kg) were created by adding 0.03% Skycis-100 premix (Elanco Animal Health, Indianapolis, IN) to diets at the expense of corn.

[5]Provided per kilogram of complete diet: 6,125 (4,594) IU of vitamin A; 700 (525) IU of vitamin D; 50 (37.5) IU of vitamin E; 3.0 (2.3) mg of vitamin K; 56 (42) mg of niacin; 27 (20.3) mg of pantothenic acid; 11 (8.3) mg of riboflavin; 0.05 (0.04) mg of vitamin B_{12}, in Exp. 1; with the numbers in parenthesis representing the levels in Exp. 2 and 3.

[6]Provided per kilogram of complete diet: Zn, 165 mg as $ZnSO_4$; Fe, 165 mg as $FeSO_4$; Mn, 39 mg as $MnSO_4$; Cu, 16.5 mg as $CuSO_4$; I, 0.3 mg as $Ca(IO_3)_2$; and Se, 0.3 mg as Na_2SeO_3.

[7]Based on the GE of the diet and apparent total tract digestibility of GE as reported in Exp. 1, 2, and 3.

Table 2. Impact of diet composition and narasin supplementation on pig performance and on energy, nutrient, and fiber digestibility in 9- to 23-kg pigs, Exp. 1[1]

		Performance			Digestibility coefficient, %								
Diet	Narasin	ADG	ADFI	G:F	GE	DM	C	N	S	Ca	P	NDF	ADF
CSBM	No	0.536	0.843	0.646[b]	84.34[a]	85.06[a]	85.40[a]	79.57[a]	77.77[ab]	66.86	55.59[bc]	43.92[a]	59.89[a]
CSBM	Yes	0.606	0.891	0.686[a]	82.65[a]	83.50[a]	83.64[a]	80.44[a]	77.76[ab]	68.26	52.93[c]	28.84[c]	51.86[b]
DDGS	No	0.550	0.780	0.701[a]	78.22[b]	79.86[b]	79.43[b]	74.69[b]	76.32[b]	72.05	57.36[ab]	36.89[b]	59.29[a]
DDGS	Yes	0.595	0.862	0.691[a]	79.86[b]	81.00[b]	80.82[b]	78.97[a]	79.42[a]	73.74	60.12[a]	41.73[ab]	62.32[a]
SEM		0.019	0.024	0.012	0.738	0.621	0.690	0.919	0.668	1.500	1.333	2.370	1.390
Source of variation, *P* value													
Diet		0.94	0.05	0.01	0.01	0.01	0.01	0.01	0.88	0.01	0.01	0.23	0.01
Narasin		0.01	0.01	0.19	0.97	0.74	0.80	0.01	0.02	0.31	0.97	0.04	0.08
Diet × Narasin		0.51	0.47	0.03	0.03	0.03	0.03	0.07	0.02	0.92	0.05	0.01	0.01
Main effects													
CSBM		0.571	0.867	0.666	83.50	84.28	84.52	80.01	77.77	67.56	54.26	36.38	55.87
DDGS		0.573	0.821	0.696	79.04	80.43	80.12	76.83	77.87	72.89	58.74	39.31	60.81
	No	0.543	0.812	0.673	81.28	82.46	82.41	77.13	77.04	69.46	56.47	40.41	59.59
	Yes	0.600	0.877	0.689	81.25	82.25	82.23	79.71	78.59	71.00	56.53	35.28	57.09

[a–c]Means within a row with different superscripts differ.

[1]Initial BW = 9.0 kg, SD = 1.0 kg; final BW = 22.7 kg, SD = 2.6 kg. The trial lasted 24 d with 16 individually penned gilts per treatment. Digestibilities calculated from fresh feces collected on d 23 and 24. Diets containing narasin contained 30 mg narasin/kg diet. Abbreviations: CSBM = corn-soybean meal based diet, DDGS = diet containing distillers dried grains with solubles based diet.

absorbance were measured using a UV spectrophotometer (Method 988.05; AOAC, 1978).

Calculations and Statistical Methods

Data in each experiment were analyzed as a completely randomized design with the individual pig as the experimental unit. Treatments were arranged in a 2 × 2 factorial design with the main effects being diet type (CSBM or DDGS) and narasin addition (no or yes). Data were identified and removed as an outlier if the value was greater than 2 SD above or below the individual treatment mean. All data were subjected to analysis of variance using Proc GLM (SAS Inst. Inc., Cary, NC) with treatment means reported as LSMEANS and differences considered significant at $P \leq 0.05$.

RESULTS

In Exp. 1, there was an interaction between diet type and narasin addition for G:F and for many of the ATTD coefficients measured ($P \leq 0.05$) Table 2. In general, when narasin was supplemented to the CSBM diet, ATTD of GE, DM, C, S, phosphorus, NDF, and ADF were either not changed or numerically reduced; in contrast, when narasin was supplemented to the DDGS containing diet, the ATTD of these same parameters were numerically increased (interaction, $P \leq 0.05$). Even though ADG and ADFI were not affected, G:F was improved in pigs fed the CSBM diet with supplemental narasin, but was numerically reduced in pigs fed the DDGS diet with supplemental narasin (interaction, $P < 0.05$). When interactions were not present, narasin increased ADG, ADFI, and ATTD of N ($P < 0.01$), while pigs fed the DDGS diets exhibited reduced ADFI and ATTD of N ($P < 0.05$), but increased ATTD of Ca ($P < 0.01$).

In Exp. 2, there was an interaction between diet type and narasin supplementation only for ATTD of Ca (interaction, $P < 0.01$), in that narasin supplementation did not change the ATTD of Ca in pigs fed the CSBM diet, while narasin supplementation reduced the ATTD of Ca in pigs fed the DDGS containing diet Table 3. When interactions were not present, narasin supplementation improved ATTD of N, but decreased ATTD of phosphorus and ADF ($P < 0.05$). Pigs fed the DDGS diets had reduced ATTD of GE, DM, C, N, and NDF, but increased ATTD of S, phosphorus, and ADF ($P < 0.05$).

In Exp. 3, there was an interaction between diet and narasin only for ATTD of C (interaction, $P < 0.01$) in that narasin supplementation resulted in a numerical increase ATTD of C in pigs fed the CSBM diet, while narasin supplementation to the DDGS containing diet resulted in a reduced ATTD of Ca, Table 4. When interactions were not present, narasin supplementation reduced ATTD of S ($P < 0.05$), while pigs fed the DDGS diets had reduced ATTD of GE, DM, and N ($P < 0.05$).

DISCUSSION

Because ionophores are known to affect hind gut bacterial populations and fermentation products (Rich-

Table 3. Impact of diet composition and narasin supplementation on pig performance and on energy, nutrient, and fiber digestibility in 81- to 103-kg pigs, Exp. 2[1]

		Performance			Digestibility coefficient, %								
Diet	Narasin	ADG	ADFI	G:F	GE	DM	C	N	S	Ca	P	NDF	ADF
CSBM	No	1.053	3.399	0.296	84.61	85.58	85.95	78.96	72.65	52.39[a]	37.44	46.50	65.47
CSBM	Yes	1.018	3.523	0.292	85.18	86.05	86.34	80.58	72.79	52.95[a]	36.37	45.71	59.14
DDGS	No	1.082	3.576	0.298	78.58	79.84	79.79	71.79	74.58	55.16[a]	47.71	41.08	71.15
DDGS	Yes	0.971	3.436	0.287	79.17	80.37	80.45	76.11	74.46	45.23[b]	41.41	38.72	68.41
SEM		0.043	0.077	0.008	0.537	0.501	0.525	0.884	0.635	2.031	1.632	2.319	1.394
Source of variation, *P* value													
Diet		0.84	0.56	0.90	0.01	0.01	0.01	0.01	0.01	0.23	0.01	0.01	0.01
Narasin		0.10	0.92	0.43	0.29	0.32	0.32	0.01	0.99	0.03	0.03	0.50	0.01
Diet × Narasin		0.39	0.09	0.69	0.99	0.95	0.80	0.13	0.84	0.01	0.12	0.74	0.20
Main effects													
CSBM		1.035	3.461	0.294	84.90	85.81	86.15	79.77	72.72	52.67	36.91	46.11	62.30
DDGS		1.027	3.506	0.293	78.87	80.11	80.12	73.95	74.52	50.19	44.56	39.90	69.78
	No	1.067	3.487	0.297	81.60	82.71	82.87	75.37	73.62	53.78	42.58	43.79	68.31
	Yes	0.995	3.480	0.290	82.15	83.21	83.40	78.34	73.63	49.09	38.89	42.22	63.77

[a,b]Means within a row with different superscripts differ.

[1]Initial BW = 81.1 kg, SD = 6.1 kg; final BW = 102.5 kg, SD = 7.1 kg. The trial lasted 21 d with 15 individually penned gilts per treatment. Digestibilities calculated from fresh feces collected on d 20 and 21. Diets containing narasin contained 30 mg narasin/kg diet. Abbreviations: CSBM = corn-soybean meal based diet, DDGS = diet containing distillers dried grains with solubles based diet.

ardson et al., 1976; Schelling, 1984; Holzgraefe et al., 1985a; Russell, 1987; Marounek et al., 1997; Wuethrich et al., 1998), we expected an effect on nutrient digestibility and animal performance due to narasin supplementation. In Exp. 1, for 9- to 23-kg pigs, there was a consistent improvement in ATTD of energy and most dietary components evaluated due to supplementation of narasin in the diet containing DDGS, while the opposite effect was noted in pigs fed the CSBM diet. In heaver pigs, however, an interaction between diet type and narasin supplementation was only noted for Ca in pigs from 81 to 103 kg (Exp. 2) or for C in pigs from

Table 4. Impact of diet composition and narasin supplementation on pig performance and on energy, nutrient, and fiber digestibility in 121- to 151-kg pigs, Exp. 3[1]

		Performance[2]			Digestibility coefficient, %[3]								
Diet	Narasin	ADG	ADFI	G:F	GE	DM	C	N	S	Ca	P	NDF	ADF
CSBM	No	0.607	2.711	0.225	90.07[a]	90.69[a]	91.04[a]	89.23	83.99	54.12	48.24	67.52	69.63
CSBM	Yes	0.645	2.786	0.234	90.25[a]	90.95[a]	91.25[a]	89.63	82.45	47.92	45.43	67.21	72.03
DDGS	No	0.658	2.699	0.249	86.57[b]	87.27[b]	87.97[b]	85.78	83.46	48.52	45.69	68.23	70.05
DDGS	Yes	0.585	2.649	0.222	84.50[c]	85.18[c]	85.43[c]	84.16	81.16	47.39	43.37	61.59	65.05
SEM		0.062	0.051	0.022	0.676	0.674	0.626	0.705	0.753	2.216	2.202	2.878	2.263
Source of variation, *P* value													
Diet		0.94	0.15	0.79	0.01	0.01	0.01	0.01	0.23	0.17	0.30	0.40	0.16
Narasin		0.78	0.82	0.69	0.17	0.21	0.07	0.39	0.01	0.11	0.25	0.23	0.57
Diet × Narasin		0.37	0.23	0.42	0.10	0.09	0.03	0.16	0.61	0.26	0.91	0.28	0.11
Main effects													
CSBM		0.626	2.748	0.229	90.16	90.82	91.15	89.43	83.22	51.02	46.84	67.37	70.83
DDGS		0.621	2.674	0.235	85.53	86.23	86.70	84.97	82.31	47.95	44.53	64.91	67.55
	No	0.633	2.705	0.237	88.32	88.98	89.51	87.50	83.72	51.32	46.97	67.88	69.84
	Yes	0.615	2.717	0.228	87.37	88.06	88.35	86.89	81.80	47.65	44.40	64.40	68.54

[a–c]Means within a row with different superscripts differ.

[1]Diets containing narasin contained 30 mg narasin/kg diet. Abbreviations: CSBM = corn-soybean meal based diet, DDGS = diet containing distillers dried grains with solubles based diet.

[2]Performance relates to pigs in metabolism crates offered 3.0 kg/h/d for a period of 48 d. Average initial BW = 121.0 kg, SD = 11.5 kg and final BW = 151.0 kg, SD = 7.9 kg.

[3]Data obtained from 12 individually penned gilts per treatment during a 6-d total collection period following 30 d of adaptation. Average BW = 145.1 kg, SD = 7.8 kg.

121 to 151 kg (Exp. 3). The fact that interactions between diet type and ionophore supplementation were not consistent in the current trial was not surprising given that others have shown inconsistent digestibility effects due to ionophore supplementation or between diet type and ionophore supplementation (Holzgraefe et al., 1985b; Moore et al., 1986a; Thacker et al., 1992; Wuethrich et al., 1998). The lack of any consistent effect of narasin on mineral digestibility is also supported by others who have shown variable or no impact of ionophore supplementation on mineral digestibility (Holzgraefe et al., 1985b; Moore et al., 1986b).

Similar to the effects of narasin on ATTD coefficients as affected by BW, only in Exp. 1 did we note any effect of narasin on pig performance. The loss of dietary effects on pig performance due to age was not surprising because of: 1—adaptation of pigs to higher-fiber diets (Gargallo and Zimmerman, 1981; Johnson, 1988; Edwards, 1993; Le Goff et al., 2002), 2—antibiotic responses are often reduced with heavier pig BW (Cromwell, 2001; Dritz et al., 2002), and 3—the current experiments were designed to evaluate energy and nutrient digestibility and not necessarily pig performance where in the current experiment pigs were individually penned, which are typical in digestibility-type trials compared to group-penned pigs and lacked the number of replications reported in commercial performance studies (Arkfeld et al., 2015). In many circumstances, ionophores have been reported to improve pig performance. Blair and Shires (1981), Leeson et al. (1981), and Lindemann et al. (1985) all reported that salinomycin increased growth performance of growing swine fed a CSBM-based diet, while Wheelhouse and Groves (1985) reported that salinomycin improved performance in pigs fed a more fiber-rich diet. Likewise, monensin has been shown to improve feed efficiency in pigs fed a barley-soybean-meal-based diet (Kirkwood et al., 1990) or in pigs under disease stress (Kyriakis, 1989), and narasin has been shown to improve pig performance in growing-finishing pigs (Arkfeld et al., 2015). In contrast, others (Thacker et al., 1992; Van Lunen et al., 1992; Wuethrich et al., 1998) have reported no effect of ionophore supplementation (salinomycin, monensin or salinomycin, and narasin, respectively) on growing pig performance. In the current experiments, feeding DDGS affected performance only in the young pig and generally decreased ATTD of energy and many of the nutrients measured. Our data are supported with previously published data sets on the impact of feeding DDGS on ATTD of energy and nutrients and growth performance in pigs, which has been discussed extensively elsewhere (Stein and Shurson, 2009; Cromwell et al., 2011; Gutierrez et al., 2013, 2014a,b; Kerr et al., 2013, 2015a,b; Wu et al. 2016a,b,c), and was not one of the main objectives of the current experiment.

In conclusion, the data indicate that narasin interacted with and had its largest effect on pig performance and GE or nutrient digestibility in 9- to 23-kg pigs compared to pigs weighing greater than 80 kg, with the data in finishing pigs being inconsistent. The data also indicate that addition of DDGS reduced GE, DM, Ca, and N digestibility, regardless of BW.

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